# INDIANA COMMERCAL ENERGY CODE BASELINE STUDY

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## Report Prepared for

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# INDIANA COMMERCIAL BASELINE STUDY

## ABSTRACT

The goal of the Indiana Commercial Energy Code Baseline Study was to assess current commercial building practice (e.g. lighting levels and building envelope compliance margins) and how it compared to the 2000 International Code Council International Energy Conservation Code (IECC). Due to the extended grant timeline, this comparison was modified to the 2003 IECC. The Indiana Department of Fire and Building Services worked in collaboration with the International Code Council (ICC) and Britt/Makela Group, Inc, under contract to ICC, to perform plan review and on-site field inspection of 55 new construction commercial buildings in key growth areas of Indiana. The review focused on determining if the building plans submitted for permit complied with the energy code, and then if the building constructed on-site was built to the plans and the code. Code enforcement personnel, who do not currently enforce the commercial energy code, conducted the onsite inspections, collecting construction data to provide a baseline of "typical" commercial construction. Problem areas in energy code compliance were identified and documented during this study.

Several different commercial occupancies were included in the baseline study including, but not limited to retail, office, school, medical and grocery projects. On average, the building envelope for the projects that were reviewed were found to be in compliance with the thermal provisions of the 2003 IECC except for buildings constructed with uninsulated concrete masonry unit wall systems. The HVAC systems reviewed as part of the study were typically found to be in compliance with several of the requirements within the IECC. Compliance with the heating and cooling load sizing requirements was not assessed as part of the study.

Lighting design will be the greatest challenge for the state of Indiana if it moves toward adoption of the 2003 IECC. The proposed lighting system wattage tended to be above that allowed by the 2003 IECC for most single occupancy buildings. Multiple occupancy buildings tended to install lighting systems that met the allowed lighting requirements. Compliance with the switching requirements in the IECC is not being met with current practice.

Adoption of the 2003 IECC (or its successor the 2006 IECC) is recommended provided training and technical assistance is deployed for the building, design and enforcement industry.

# SECTION 1.0 INTRODUCTION

The Indiana Commercial Energy Code Baseline Study is part of the Indiana Education Program, funded through the Indiana Department of Commerce, Energy and Recycling Division by a Codes and Standards grant from the U.S. Department of Energy. The following project partners participated in the grant:

- Indiana Department of Commerce, Energy and Recycling Division
- Indiana Department of Fire and Building Services (IDFBS)
- International Code Council (ICC)
- Britt/Makela Group, Inc (BMG)

The goal of the baseline study was to assess current commercial building practice (e.g. lighting levels and building envelope compliance margins) and how it compared to the 2000 International Code Council International Energy Conservation Code (IECC). Due to the length of the grant this comparison was modified to the 2003 IECC. IDFBS worked in collaboration with ICC and BMG to perform plan review and on-site field inspection of 55 new construction commercial buildings in key growth areas of Indiana. The review focused on determining if the building plans submitted for permit complied with the energy code, and then if the building constructed on-site was built to the plans and the code. Code enforcement personnel, who do not currently enforce the commercial energy code, conducted the onsite inspections, collecting construction data to provide a baseline of "typical" commercial construction. Problem areas in energy code compliance were identified and documented during this study.

The report that follows first provides the findings of the study for both the plan review and inspection portion of the project. The findings are presented based on the energy using features of the building i.e. the building envelope, mechanical system and lighting system. A discussion of the data collection process follows the findings. Recommendations for energy code adoption and implementation are then presented based on the project findings.

### *Section 1.1 Occupancy Distribution*

To provide a broad assessment of commercial construction practices, every effort was made to include a broad range of typical occupancies that represented typical construction in the state of Indiana. The original sample size was set at 50 commercial buildings and five additional buildings were added at the end of the study to increase the building representation and increase the total to 55. The project was limited to plans and projects that were submitted for review to the IDFBS to ensure that the buildings would be in the construction phase during the study. Staff at IDFBS assisted in the selection of projects to ensure that projects selected were representative of the permits issued. This limitation affected the sample size of certain occupancies, e.g. schools, as there were a limited number submitted when the projects were selected for the study. The other goal of the sample selection was to include projects that will be common permit submittals such as tenant improvements where the building shell is already constructed and a permit is pulled for only the mechanical and lighting system. These projects are typical for strip shopping center and office/warehouse development. The project also selected projects that are considered “alterations” under the IECC. An alteration is considered any increase or decrease to the energy using feature of the building, for example changing out a lighting system in a portion of the building. Alterations can comprise a high percentage of new permit applications in more urban areas.

An effort was also made to select plans that had adequate information to determine compliance with the IECC. Structural plans are only required for certain project types and did contain adequate information to determine compliance for the building envelope, lighting or mechanical systems. These types of plans were not selected because no useful information would be available for the study.

## SECTION 2.0 FINDINGS

### *Section 2.1 Introduction*.

The study analysis provided findings with regards to the building envelope, mechanical system and lighting. Each component was assessed to determine compliance with the 2003 IECC, which in turn provided a good assessment of potential issues that the building design and enforcement industry would face if the commercial provisions of the IECC were adopted by the state of Indiana.

Compliance was determined using the US Department of Energy’s COM*check-EZ* Version 3.0 Release 1. The software provided a compliance rate for the building envelope and lighting system, however because there are no trade-offs within the mechanical provisions of the IECC, no compliance rate is provided for this component. Instead different aspects of the mechanical system were reviewed that have been problematic in states that have adopted the IECC.

Compliance for several mandatory items cannot be assessed by the use of the COM*check-EZ* compliance tool. These include requirements such as switching for lighting, air sealing for the building envelope, and duct insulation for the mechanical system. Typically these requirements are covered using plan notes and addressed in the field. A portion of this study reviewed compliance with these requirements by current practice where possible.

### *Section 2.2 Occupancy Type*

Table 2.2(1) provides a distribution of the single occupancy buildings that were selected for the study. Office, restaurant and retail occupancies were the predominate building type selected for the study representing 44% of the sample size. Several modular classroom buildings were permitted by the state and two were selected for the analysis. Two multi-family buildings were selected as they are considered to be commercial buildings under the Indiana Building Code.

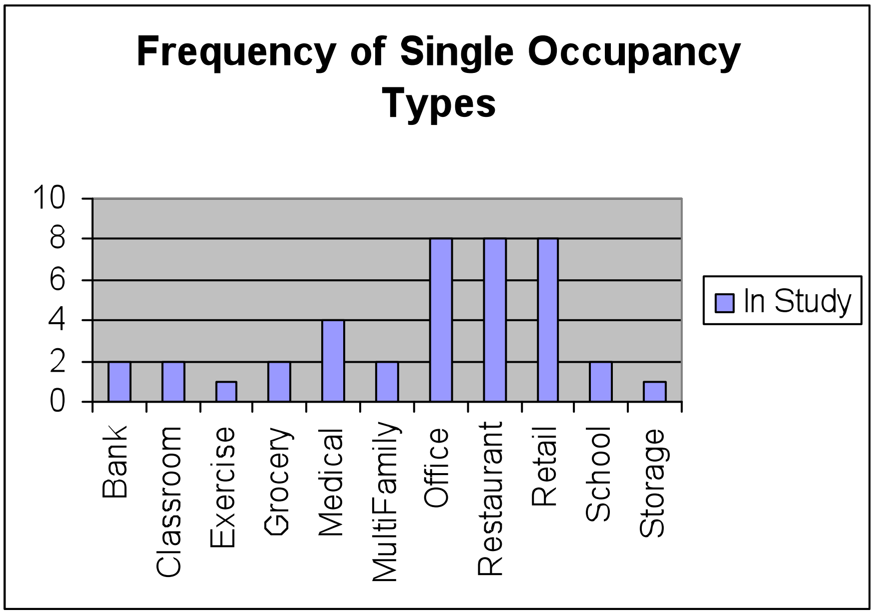


**Table 2.2(1) Single Occupancy Type Buildings**

Table 2.2(2) provides a distribution of the multiple occupancy buildings that were selected for the study. These type of buildings are classified as having no major occupancy or having a conditioned occupancy and large percentage of the building considered either storage or warehouse. For example a retail space also had a high percentage of office space associated with it. These classifications will affect the lighting power densities assigned to each of the buildings but do not affect the building shell as all of the spaces were conditioned and covered under the commercial provisions of the IECC.

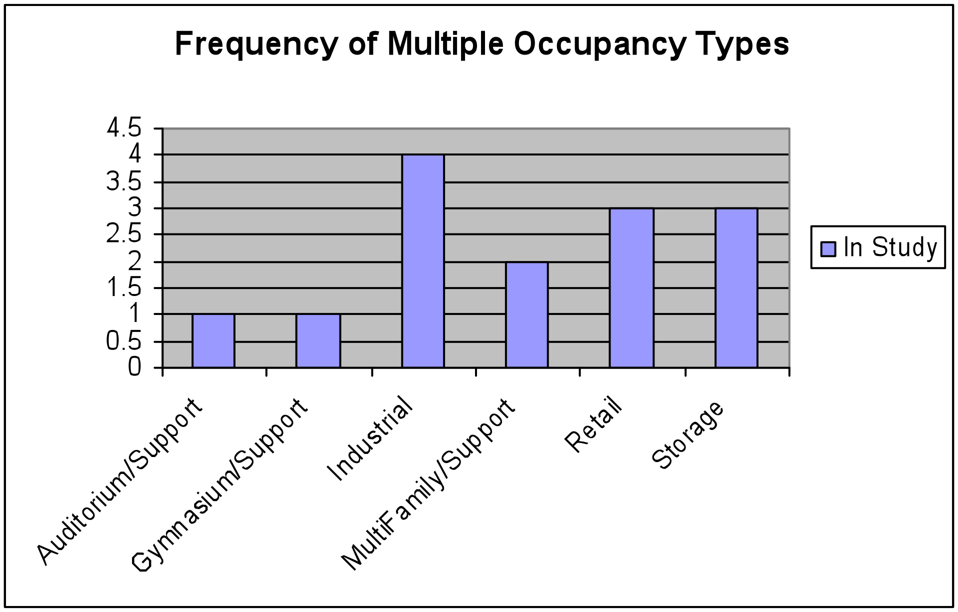


**Table 2.2(2) Multiple Occupancy Type Buildings**

The industrial storage buildings were the predominate multiple occupancy buildings. The storage and retail classifications both included office space. The multifamily included student dormitories which are classified as a commercial occupancy under the IECC.

### *Section 2.3 Building Envelope*

The building envelope for 43 of the projects were analyzed using COM*check-EZ*. The buildings represented typical construction and included wood and steel framed and walls constructed with concrete masonry units (CMU) or a combination of wall types. The roof assemblies included both wood and non-wood truss systems and metal roof assemblies. Foundation types were typically slab-on-grade. The data was collected from the plans to determine compliance with the insulation and glazing requirements in addition to information concerning the mandatory requirements. This information was then confirmed by the field data collection team when possible.

**Section 2.3.1 Plan Review**. Plan review for the building envelope highlighted areas that are consistent problems in states that have adopted commercial energy codes.

Section 2.3.1.1 Insulation and Glazing. Insulation levels for the roof/ceiling assembly, wall assembly and floor assembly were collected for use in the COM*check-EZ* compliance runs and to determine a typical insulation level for these assemblies. Glazing area, U-factor and solar heat gain coefficient information was also collected to determine if the building complied with the IECC.

*Section 2.3.1.1.1 Floor Types*. The predominant floor type was slab-on-grade construction. Only one of the buildings analyzed contained below grade walls. Only nine of the buildings analyzed had included slab edge details on the plans that complied with the provisions of the IECC. Slab edge insulation must start from the top of the slab and go vertical or vertical and horizontal to be considered an insulated slab (see Figure 2.3.1.1.1(1)).

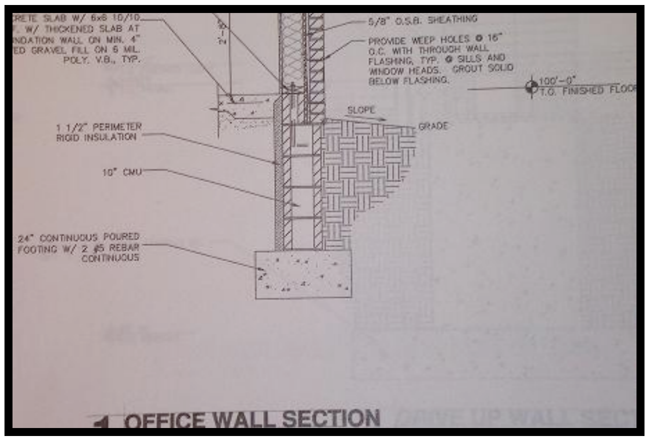


**Figure 2.3.1.1.1(1) Qualifying Slab Edge Insulation**

Those that did not comply either did not have any insulation installed or the insulation did not cover the surface of the slab edge. Figure 2.3.1.1.1(2) shows a typical slab edge detail for the commercial buildings selected for this project.

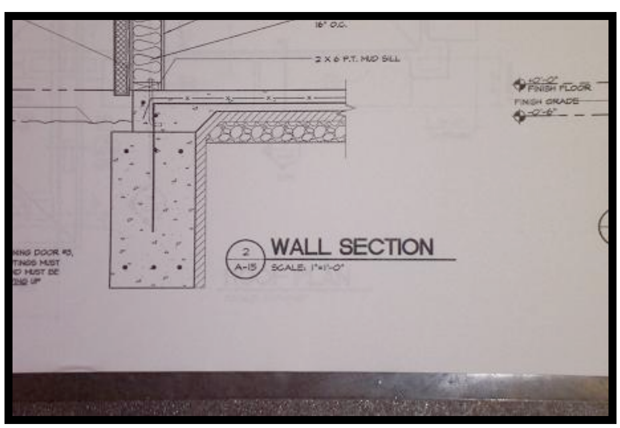


**Figure 2.3.1.1.1(2) Non-qualifying Slab Edge Insulation**

All of the slab edge insulation identified on the building plans had an R-value of R-10 regardless of the installation. Only one building had below grade walls. The walls in this project were uninsulated.

*Section 2.3.1.1.2 Wall Types and Insulation R-value.* During the plan review portion of the baseline study, the exterior wall type and proposed insulation R-value were recorded in addition to the gross wall area. This information was used for the COM*check-EZ* input and to also determine the typical type of wall construction. The buildings that were selected represented several different types of wall construction (see Table 2.3.1.1.2).

| **Wall Types** | |
|---|---|
| Wood Framed | 22 |
| Metal | 11 |
| CMU<=8" | 7 |
| CMU<=8" w/ integral insulation | 1 |
| CMU>8" | 3 |
| Concrete | 2 |
| Metal w/o Thermal Break | 1 |
| Note: Total walls greater than number of compliance runs, due to multiple walls per structure | |

**Table 2.3.1.1.2**

Twenty-two (51%) of the buildings used wood framing for the exterior walls. Wood framing was used on a variety of occupancy types ranging from offices to restaurants. Wood frame construction was also used in conjunction with other wall types including concrete masonry unit (CMU). Buildings using CMU or concrete construction comprised 30% of the projects selected for the study. The CMU blocks were typically $\leq$ 8" and only one of the buildings called out integral insulation installed in the cells of the block. CMU or concrete was often used in conjunction with wood or metal framing.

All of the wood walls were insulated with cavity insulation. The average R-value for the proposed insulation, based on building population, was an R-16.7. The R-value for the wood walls ranged from a low of R-11 (4.3%) to a high of R-19 (64%). Only one of the walls also included continuous insulation which was an R-2.5.

Metal framed walls were categorized together to assess insulation values. The average R-value proposed for this wall type, based on building population, was an R-15.9. The R-values ranged from an R-10 (one building) to an R-19 (8 buildings). One of the structures contained metal walls showed no insulation.

This wall system was found to be out of compliance with the minimum metal wall insulation requirements integrated into the COM*check-EZ* software.

CMU and other concrete walls varied from no insulation to insulation installed between furring on the inside of the wall systems. Five of the seven CMU ≤ 8" walls contained no insulation. These walls were found to be out of compliance with the minimum CMU/concrete wall insulation requirements integrated into the COM*check-EZ* software for the applicable Climate Zones. Only two of the seven wall systems discussed above were insulated with R-10 or R-11 insulation installed between furring.

Only two buildings contain CMU > 8". One was insulated to an R-11 in the between furring and the other was uninsulated. As with the uninsulated CMU ≤8" the wall system was found to be out of compliance with the minimum insulation requirements within COM*check-EZ.* Two buildings contained concrete wall systems with one insulated with furring and R-10 insulation on the exterior of the wall.

*Section 2.3.1.1.3 Roof/Ceiling Assemblies and R-values.* Three roof/ceiling assemblies were represented during the baseline study (see Table 2.3.1.1.3).

| **Roof Types** | |
|---|---|
| Wood | 27 |
| Non-Wood | 11 |
| Metal w/o Thermal Break | 5 |

**Table 2.3.1.1.3**

The predominant roof type was a wood truss system. This type of roof system was installed on over 63% of the buildings where the envelope was evaluated. Non-wood joists or trusses were the next highest category representing 26 percent of the building envelope sample.

For roof systems constructed of wood truss systems, 63% installed insulation between the framing (cavity insulation). The average R-value for this insulation was an R-32. This average represented a low of R-11 (one roof system) to a high of R-40 (one-roof system). Nine were insulated to an R-30 with six insulated to an R-38. It was unclear if the insulation was to be blown-in or fiberglass batt.

Insulation was placed on the roof decking (continuous) for ten of the wood framed roof systems. The insulation values shown on the plans ranged from an R-12 to an R-30 with an average based on number of buildings or R-20.9. Four of the buildings proposed an R-20 continuous insulation while the remaining roofs had an R-14, 21, 24 and 28 installed.

For non-wood joist or truss roof systems, two buildings had proposed to install insulation between the framing members. Based on the building plans one had proposed to install an R-12 and the other an R-21. The remaining nine roof systems proposed insulation placed on top of the roof deck with an average R-value of 17 for the buildings studied. The buildings ranged from a low of R-10 to a high of R-28.

Metal roof systems insulated between framing typically installed an R-19. Only one metal roof system installed continuous insulation to an R-10 and one roof system proposed no roof insulation. This building failed the mandatory minimum R-value requirement contained with COM*check-EZ* for the proposed Climate Zone.

*Section 2.3.1.1.4 Glazing Percentage, U-factor and SHGC.* The rough openings were used for window area to determine the percent glass to gross exterior above grade wall area. Table 2.3.1.1.4(1) displays the distribution of glazing percentages and their frequency. The glazing percentages were categorized based on the prescriptive envelope tables from Chapter 8 of the 2003 IECC. Over 53% of the buildings reviewed for compliance with the building envelope had glazing percentages between 0 to 10% and over 88% have glazing percentages less than or equal to 25% of the gross wall area.

| **Percent Glass to Gross Exterior Above Grade Wall Area** | |
|---|---|
| **Percentage of Wall Area** | **Frequency** |
| 10% or Less | 23 |
| Greater than 10% but not Greater Than 25 Percent | 15 |
| Greater than 25% But Not Greater Than 40 Percent | 5 |

**Table 2.3.1.1.4(1)**

Limited plan review data was available to determine typical glazing U-factor and SHGC for the projects. This is typical for most building plans that have adopted in states that have adopted the IECC. Standard practice is to reference the energy code compliance documentation, e.g. COM*check-EZ* Compliance Report, for the efficiencies of the products being installed. Information on glazing type (e.g. single or double glazed) and frame type (e.g. metal or thermally broken metal) may be called out in the plan set for projects but this is not a certainty. Also, glazing SGHC values are normally not called out on the building plans but may be identified in the project specifications. The normal description is to use clear or tinted to identify the window properties or in some cases the actual tint (e.g. Solar Bronze) is specified. Table 2.3.1.1.4(2) provides a description of the types of windows that were found in the building plans and the frequency of their findings. Based on the information from the plans metal double pane windows were the predominant window type. These occurred on several occupancy types but are used extensively for store front, curtain wall and site built glazing. Vinyl framed windows were found in a portion of the projects.

| Window Types | |
|---|---|
| **Type of Window** | **Frequency** |
| Metal Frame / Double Pane | 27 |
| Metal Frame / Double Pane Low E | 4 |
| Thermally Broken Metal Frame / Double Pane | 3 |
| Vinyl Frame / Double Pane | 8 |
| Wood Frame / Double Pane | 3 |

**Table 2.3.1.1.4(2)**

Default U-factor and SHGC values were used in most cases to determine compliance with the 2003 IECC using COM*check-EZ.* The values contained in COM*check-EZ* are based on the 1989 ASHRAE Handbook of Fundamentals. Unless specific information was found in the building plans or onsite, the windows were assumed to be clear. This was a very conservation assumption but is consistent with the IECC when glazing properties are not known.

Section 2.3.1.2 Mandatory Requirements*.* Several mandatory requirements were reviewed as part of the plan review process. These are requirements that are typically enforced during the inspection process. In states that have adopted the IECC, plan notes are normally included to ensure that the features are installed in the building. The five mandatory requirements that were reviewed as part of the baseline study included:

- Air sealing holes and penetrations in the building envelope
- Vapor retarders installed in unvented framed walls, floors and ceilings
- Insulated Contact (IC) rated air tight recessed can lights installed in the building envelope
- Vestibules for exterior doors leaving from spaces greater than 3,000 $ft^2$
- Weather seals on loading dock doors

During the plan review process, plan notes were identified on four projects requiring penetrations in the building envelope to be sealed up. A reference to vapor retarders was found either as a plan note or in a construction detail for seven of the projects reviewed. References to IC rated air tight recessed can lights were found on the plan sets for thee projects. Weather seals for loading dock doors were not found on any of the project plans.

Vestibules were found on 18 of the projects reviewed during the plan review stage. Those complying with the IECC were required to have self-closing doors into and out of the space as shown in Figure 2.3.1.2 and will lead to reduced infiltration into the space. The vestibule requirement will always need to be shown on the floor plan to ensure compliance with the IECC.

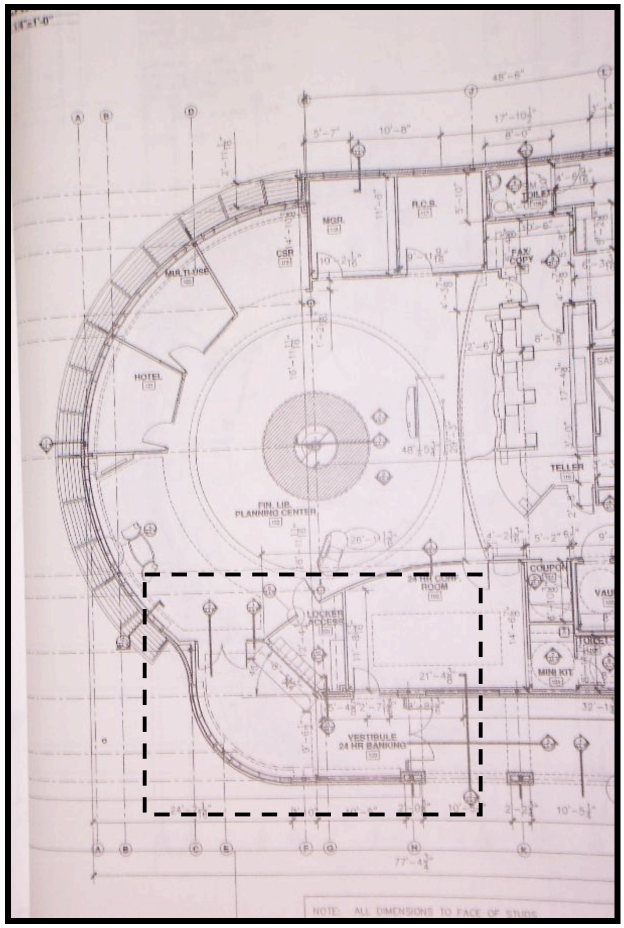


**Figure 2.3.1.2 Vestibule (Shown in Box)**

Section 2.3.1.3 Envelope Compliance Margins*.* The compliance margins were determined for each of the buildings reviewed for building envelope compliance using COMcheck-EZ. The buildings were compared against the envelope requirements for the 2003 IECC which were identical to the 2000 IECC. Average compliance margins for the population of buildings were compared against glazing percentage and wall construction type. Building envelope compliance is based on glazing percentage with greater levels of thermal efficiency required to demonstrate compliance as glazing area increases. Wall construction also is a determining factor in compliance because it is more difficult to determine compliance with the 2003 IECC if the walls have low insulation values. As stated above, compliance for the building envelope could not be determined for a portion of the projects because the R-value for the proposed wall assembly was lower than the minimum values allowed by the COM*check-EZ* software. These values were based on the ASHRAE Standard 90.1-1989 requirements for the building envelope. Typically these minimum values affect uninsulated CMU wall systems or steel framed walls with insulation values below R-13. The minimum values will also vary based on climate zone. Minimum U-factors for glazing are also required in certain climate zones which would result in noncompliance if the average U-factor was less efficient than required.

Table 2.3.1.3(1) displays average envelope compliance margins based on the percent glass to wall area. On average, the buildings complied with the envelope requirements when compared with the glazing percentage. The compliance rates drop with more glass in the building which is to be expected. Only two of the eligible buildings did not comply with the envelope provisions having compliance margins of (-)6% and (-)8% worse than code. Three of the buildings did not comply with the code for glazing percentages between 10% to 25%. These buildings had compliance margins of (-)1%, (-)11% and (-)0.1% worse than code. This is typical of higher glass buildings. For buildings in the 25% to 40% range one building did not comply with (-)29% worse than code. This was offset with a compliance rate of 20%.

**Average Compliance Margin Based on Glazing Percentage**

| Glass Percentage | Average Compliance Margin |
|---|---|
| <=10% | 19.35 |
| >10% to <=25% | 8.08 |
| >25% to <=40% | 1.00 |

**Table 2.3.1.3(1)**

Table 2.3.1.3(2) compares the average envelope compliance margin against the exterior wall type for the buildings. Average compliance rates were calculated for the population of buildings that had a specific exterior wall type. Two wall classifications showed negative compliance margins with the code. Concrete walls had a compliance margin of (-)1.67% and metal framed walls had a margin of (-)2.86% worse than compliance. Buildings constructed with CMU wall systems or wood had high average compliance margins. Wood framed walls typically perform well for building envelope compliance since they often used 2" X 6" wall systems and are insulated to R-19. No uninsulated CMU wall systems were counted in the average compliance margin because they would not meet the minimum efficiency requirements required by COM*check-EZ*.

| Average Compliance Margin Based on Wall Type | |
|---|---|
| **Wall Classification** | **Average Compliance Margin** |
| CMU<=8" | 13.67 |
| CMU>8" | 16.50 |
| Concrete | -1.67 |
| Metal | 3.00 |
| Metal Frame | -2.86 |
| Wood | 20.84 |

**Table 2.3.1.3(2)**

Two multi-family projects less than three stories in height were included in the code study. These projects are considered to be residential buildings under the 2003 IECC but are required to be submitted to the IDFBS for plan review and are considered to be commercial buildings. The envelope compliance margins were included in Tables 2.3.1.3(1) and (2). Residential compliance margins were determined for the projects using the US DOE RES*check* software. A comparison between the residential and commercial compliance margins is included in Table 2.3.1.3(3).

| Average Compliance Margin for Multi-family Buildings | | |
|---|---|---|
| **Unit Number** | **Compliance Margin Residential** | **Compliance Margin Commercial** |
| 1 | 12.1% | 18.0% |
| 2 | 2.2% | 22.0% |

**Table 2.3.1.3(3)**

As was expected, the compliance margins under the commercial code were greater than under the residential code. Higher levels of efficiency are required under the residential provisions of the IECC for insulation and glazing which accounts for the reduction of compliance margins between the two codes. Less emphasis is placed on building envelope efficiency in the commercial code than the residential provisions of the code. More emphasis is placed on reducing heat gain through the building assemblies for commercial code compliance leading to SHGC requirements for windows. Because of the differences in energy use between commercial and residential buildings it is strongly recommended that residential buildings comply with the residential provisions of the IECC and not the commercial provisions of the code.

**Section 2.3.2 Inspection.** IDFBS field inspection staff used the data collection forms from the plan review process to verify that the information shown on the plans was installed in the field (see Section 3.3 for a description of the process). In general, the inspectors were asked to verify items that were in question due to a lack of information on the building plans. They were also asked to verify several additional features for the building envelope including inspecting for compliance with the mandatory building envelope requirements.

*Section 2.3.2.1 Insulation and Glazing*. The inspectors verified the building envelope information contained in the data collection form for insulation and glazing U-factor and SHGC. They also verified that the structural make up of the building was consistent with that shown on the building plans. For example, if the plans called for CMU for the exterior walls and the inspector found the walls to be constructed using metal framing, this would have an impact on compliance with the energy code.

Overall, what was called for on the building plans was installed in the field for insulation R-values. In one case less insulation was installed on the slab edge (R-7.5 instead of R-10). The building assemblies were consistent with what was submitted and approved by the IDFBS. There were three recorded cases where the structure differed from what was shown on the plans. In one case the roof assembly used nonwood joists or trusses instead of wood trusses. In another case the steel framing was used instead of CMU construction for exterior walls. And in the final case wood wall framing was used instead of steel framing. These corrections were made to the COM*check-EZ* files for each of the buildings.

The inspectors also tried to verify glazing U-factor and SHGC values for the installed glazing. The most common comment from the inspectors was that the majority of the windows did not have identification labels listing this information. This is typical for site built windows as there are typically no National Fenestration Rating Council (NFRC) labels on the windows because the window is assembled on site and not at the manufacturer. Verifying U-factor ratings for site built windows is a common problem for states that have adopted the IECC due to the lack of NFRC labels. A portion of the windows did have NFRC labels and this information was collected. These windows were typically manufactured units and not site assembled. As discussed before, windows were assumed to be clear unless otherwise noted on the plans or documentation. In several cases, the inspectors corrected this assumption changing the window characteristics from clear to tinted.

*Section 2.3.2.2 Mandatory Requirements.* The field inspection staff verified that the information collected during plan review pertaining to the mandatory requirements (see Section 2.3.1.2) was installed in the field. For the buildings that were inspected, several of the items were installed in the field. For example, air sealing was found in more buildings than found during the plan review process. Weather seals on loading dock doors were found in the field on 4 occasions with not reference on the building plans. Fixtures rated for insulation contact and air tight were found in the field more frequently (six projects) than what was called for on the plans (3 projects). Fewer vestibules were found in the field than what was called for on the plans (10 in the field verses 19 on the plans). Not all of the buildings that were plan reviewed were inspected which accounted for part of the discrepancy. Also, the inspector may not have been clear on the vestibule requirement and therefore not recorded its existence.

Overall, there was consistency between the building plans and what was installed in the field. Based on past experience, there are fewer changes between the building plans and built structure for commercial occupancies than for residential construction. Also, there are more licensed design professionals within the commercial building industry verses the residential industry that increases the likelihood that the building will be built to plan.

### *Section 2.4 Mechanical Systems*

The 2003 IECC provides no trade-offs for the HVAC system requirements. All of the provisions that apply to a system type must be in compliance except if the system component is exempt from the requirement. The study reviewed the types of mechanical systems that were proposed for the projects and recorded data based on system type and size (cooling only) and the number of units. In addition, information was collected on several of the mandatory requirements to determine any problems or issues that might arise in the field if the 2003 IECC was adopted by the state of Indiana.

**Section 2.4.1 Plan Review.** Energy code compliance information was collected based on the COM*check-EZ* compliance input requirements. These inputs parallel Chapter 8 of the IECC. Two different data collection forms were developed for mechanical system take offs based on the division within the IECC between simple systems and complex systems. Simple systems are defined as single zone, unitary systems. A packaged rooftop gas/electric unit is considered a simple system. Complex systems consist of any system that does not fall under the definition of a simple system. This includes variable air volume systems, hydronic systems and large built-up systems. Only two of the buildings that were included in the HVAC portion of the study had systems that were classified as complex. Forty-three buildings were reviewed for compliance with the HVAC requirements of the IECC. A portion of the plans did not have complete information to determine if the design was in complete compliance with the IECC.

Section 2.4.1.1 System Type. Information on the heating and cooling system type was collected for each of the projects. The cooling system capacity and presence of an economizer was recorded when applicable. For simple systems, these two components are important in determining compliance with the IECC. Minimum equipment efficiency is also a code requirement but this information was typically not available on the plans and is normally complied with at point of manufacturer.

System type and capacity for various types of cooling equipment are displayed in Tables 2.4.1.1(1) and 2.4.1.1(2). The most HVAC system type was a rooftop package unit (RPU). Twenty seven (63%) of the projects had one or more of these units installed on the roof assembly. The RPUs were categorized based on cooling output capacity using the COM*check-EZ* size categories as guidance. Under the 2003 IECC systems with a capacity greater than 65,000 Btu/h are required to have an economizer. Based on this requirement, economizer information was collected from the plans for each system size.

| Rooftop Package Units | | |
|---|---|---|
| **Cooling System Size (kBtu/h)** | **Frequency** | **Economizer Installed** |
| **<65** | **50** | **12** |
| **≥65 to <90** | **27** | **15** |
| **≥90 to <135** | **20** | **9** |
| **≥135 to <240** | **4** | **1** |
| **≥240 to <760** | **8** | **8** |
| **≥760** | **0** | **0** |

**Table 2.4.1.1(1)**

Systems with a cooling capacity of less than 65,000 Btu/h were the most common type of systems accounting for 46% of the total number of systems installed. Of these, only twelve of the systems had specified an economizer. Systems between 65,000 Btu/h and 135,000 Btu/h counted for 43% of the total number of RPUs. Thirty-three (56%) of the systems that were required to have an economizer had one proposed for the system.

There were several other cooling system types installed as displayed in Table 2.4.1.1(2). Heat pumps were the most common type of cooling system installed other than RPUs but these systems were also installed in two student housing dormitory complexes. Central furnaces with a split system DX were the next most common cooling type. These systems are similar to residential heating and cooling systems. All of the cooling systems that were not RPUs had a capacity of less than 65,000 Btu/h with the exception of two heat pump systems that were between 65,000 and 90,000 Btu/h.

**Other Cooling System Types Installed**

| System Type | Cooling System Size (kBtu/h) | Frequency |
|---|---|---|
| Heat Pump | <65 | 61 |
| Heat Pump | ≥65 to <90 | 4 |
| Rooftop Package Heat Pump | <65 | 1 |
| Central Furnace with Split System DX | <65 | 24 |
| Package Terminal Air Conditioner | <65 | 2 |

**Table 2.4.1.1(2)**

Table 2.4.1.1(3) contains data on heating only systems. The frequency based on number of projects was recorded instead of total number of units since there are no requirements based on size of systems for heating systems within the IECC. Only the maximum capacity of the systems is limited based on heat loss calculations.

**Other Heating System Types Installed**

| System Type | Frequency (No. of Projects) |
|---|---|
| Central Furnace | 1 |
| Radiant Heat | 1 |
| Unit Heaters Electric | 2 |
| Unit Heaters Gas | 1 |

**Table 2.4.1.1(3)**

One of the multi-family projects used the water heater as the heat source for the space heating system and used an 18,000 air source condensing unit for the cooling source.

It should be noted that a portion of the projects contained more than one type of system. For example, projects could contain several RPUs with a unit heater for a storage area.

As stated above, only two of the projects where HVAC data was collected, had systems that were classified as complex. One of the buildings used a water cooled condenser with a capacity greater than 760,000 Btu/h. A steam boiler was used in conjunction with the cooling system with the heat distributed through both constant volume and variable air volume boxes. This system was used in a hospital addition where close temperature and humidity control was required. The other project was a school that used a steam boiler with a capacity of between 300,000 to 600,000 Btu/h. The cooling system used a centrifugal chiller with a capacity between 150 to 300 tons.

*Section 2.4.1.2 Duct Information.* Information on duct construction, location, insulation R-value and duct sealing was collected when possible. Information from the HVAC plans was scarce for several of the systems. The data reported in this section also includes information from the field inspectors especially as the information relates to duct insulation, duct construction and duct sealing methods.

Duct insulation R-value levels were recorded for 14 of the projects. Of the 14 projects all had insulation R-values that met or exceeded the R-5 (e.g. R-5 or R-6) minimum duct R-value requirements for ducts in unconditioned spaces. Two of the systems had duct insulation levels at R-4.2 and R-3 that did not meet the minimum requirements.

Duct location was typically in the space above the dropped ceiling or attic areas which is typical in buildings with slab-on-grade construction. The majority of the systems used a combination of sheet metal and flex ducts, using sheet metal for the main trunks and the flex to connect to the supply registers. Two systems used fiberglass duct board for the duct system. Mastic was used on 13 of the 14 systems that were reviewed to seal the ducts. UL 181 tape was found on two of the systems with duct tape also found on two of the systems. Unapproved duct tape is not allowed as a primary sealant for any duct system. Zip ties were recorded for four of the systems that used flex duct. Zip ties are also not allowed to be used as the primary sealant for duct systems.

It should be noted that in states that have adopted the 2003 IECC, HVAC system information for compliance with the energy code is typically included in the COM*check-EZ* documentation. The documentation is either included as part of the HVAC plan submittal or submitted as a separate document. The plan notes contained in the documentation are typically deemed to comply with the code for provisions such as duct insulation and duct sealing but additional information is required for capacity, economizers and equipment efficiency. This can be contained in a HVAC equipment schedule.

HVAC load calculations were not found for any of the projects. These are required to be performed in order to size systems under the 2003 IECC. Several jurisdictions that have adopted the IECC require these to be submitted for permit. Due to the absence of load calculations, there was insufficient data to determine if the equipment was sized properly.

**Section 2.4.2 Inspection.** The field inspection team used the data collection forms for the HVAC system to verify that the information presented on the HVAC plans was correct or to collect additional information missing from the plans. There were few discrepancies between the plans and what was installed in the field for the buildings were inspections occurred. As stated above, information concerning duct system type, insulation R-value, sealing methods, etc. were collected in the field where the plans were found to be deficient.

### *Section 2.5 Lighting*

Lighting system data was collected on 40 of the projects in the study. One of the goals of the study was to determine the average lighting power allotment for several types of occupancies. Compliance with the watts/ft$^2$ requirements within the 2003 IECC is proving to be difficult for certain occupancy types e.g. retail and office projects in states that have adopted the code. The other goal of the study was to review switching and control strategies for the project to determine if current practice met the requirements of the IECC. Exterior lighting was also reviewed to determine if the type of lighting installed and also if the lighting was controlled by either a photocell or time clock as required by the IECC.

Not all of the projects in the study were reviewed for compliance with the lighting requirements. Projects that submitted plans for the building envelope and mechanical systems only were excluded from the study. Also, lighting plans where the fixture type was not clearly identified on the plans, and where the field inspection team could not collect sufficient information about the lighting were excluded. Typically these plans only called out the fixture location without providing detail on type and wattage.

#### **Section 2.5.1 Plan Review.**

Plan review for the lighting systems highlighted consistent problems that have occurred in states that have adopted the IECC. It is difficult to gain compliance with the retail lighting requirements for the 2003 IECC. Also, the type of lighting sources may need to be of a higher efficacy than used in current practice. The lighting design must also be addressed for several occupancies to ensure that sufficient lighting is provided given the lighting power allowance for the project.

Fixture wattage was not provided in the lighting schedule for several of the lighting plans. The default wattage provided within COM*check-EZ* was used in these cases. This practice is typical in states where fixture wattage is not known and is considered to be conservative i.e. the values within the software are greater than the actual fixture wattage.

Section 2.5.1.1 Interior Lighting Power. Table 2.5.1.1(1) displays the Lighting Power Densities (LPD) for occupancy classifications within the study for 28 of the projects. The projects represent "single occupancy" buildings where there was a clear single occupancy for the building. For example a retail space with small office included would be classified as a single occupancy space. The Allowed Watts/ft$^2$ is provided as a basis of comparison for the Actual Watts/ft$^2$ taken from the lighting plans. The Allowed Watts/ft$^2$ is based on the whole building approach as described in the IECC. No additional lighting allowances were taken for retail display lighting, decorative lighting, visual display terminals or medical lighting as allowed by the 2003 IECC. There was not adequate information on the lighting plans to accurately determine the additional lighting allowed by the code for these uses. Also, the Whole Building Lighting numbers are consistent with the lighting allowances that will be published in the 2006 IECC currently under consideration by the state of Indiana. A Compliance Rate is also presented to determine the average percent above or below compliance for the occupancies in the study.

As shown in the table, only the grocery occupancy complied on average with the lighting power densities. Retail lighting was 30.7% on average worse than IECC requirements. The highest actual LPD was 2.8 watts/ft$^2$ while one project came in at 1.03 watts/ft$^2$ significantly lower than what was allowed. The remaining retail occupancies ranged from 1.9 to 2.3 watts/ft$^2$. As stated above, the additional lighting allowances for retail display lighting were not calculated for these projects due to lack of information on the plans. An additional 1.6 watts/ft$^2$ for general merchandise display and 3.9 watts/ft$^2$ for items that specifically require greater display lighting can be used which would result in lower actual LPDs for retail.

Two of the restaurant projects had actual LPDs less than the allowed 1.6 watts/ft$^2$ coming in at 1.0 and 1.1 watts/ft$^2$. The remaining projects ranged between 1.7 and 2.9 watts/ft$^2$. Additional lighting is available for restaurant occupancies for decorative lighting that may bring the actual LPD closer to the allowed LPD.

Office lighting was significantly greater on average than what was allowed. None of the projects reviewed complied with the 1.0 watts/ft$^2$ allowed by code. The actual LPD was closer to the “rule of thumb” LPD for office lighting of 1.5 watts/ft$^2$ allowed under past commercial energy codes. Lighting design for offices will be significantly impacted under the 2003 IECC.

The actual LPD for classroom lighting represents only one project and should not be mistaken for current practice in the state of Indiana. This project represented a research classroom which typically requires higher lighting levels. Specialized research lighting can be exempted from compliance with the lighting requirements of the code. There was not enough detail on the lighting plans to differentiate between research lighting and general lighting in order to take this exemption.

**Lighting Power Densities Single Occupancies**

| Occupancy Category | Allowed Watt/Sq/Ft. | Actual Watt/Sq. Ft. | COMCheck Compliance Rate |
|---|---|---|---|
| Retail | 1.5 | 2.0 | -30.7 |
| Restaurant | 1.6 | 1.8 | -9.3 |
| Office | 1 | 1.5 | -51.6 |
| Medical | 1.2 | 1.4 | -20.3 |
| Bank | 1.5 | 1.6 | -4 |
| Grocery | 1.5 | 1.4 | 8 |
| School | 1.2 | 1.5 | -29 |
| Classroom | 1.4 | 5.17 | -270 |

**Table 2.5.1.1(1)**

Table 2.5.1.1(2) represents projects that had multiple uses within the building and could not be classified as a single use building. These building typically did not have a predominant use as with the single occupancy buildings. Often the projects had a large percentage of floor area used for storage or support. For example, one medical building addition had a high percentage of storage associated with the medical office and examination areas. Projects that did not have an allowed LPD using the Whole Building Approach were also put into this category. For example an addition to one project consisted of a gymnasium and support occupancies. Because these projects represent typical construction in both Indiana and in other states that have adopted the 2003 IECC it was important to address these projects separately and not try to classify them as a single occupancy building.

COM*check-EZ* was used to generate the allowed LPDs for use as a comparison. The Tenant or Portion of Building allowed LPD numbers were used from the IECC. The allowed LPD will vary based on the area of each occupancy within the building. Based on the proposed plans the majority of the projects complied with the allowed LPD value. Two of the projects associated with an office did not comply with the IECC. One of the retail and restaurant projects also did not comply.

| Lighting Power Densities Multiple Occupancies | | | |
|---|---|---|---|
| Occupancy Category | Allowed Watt/Sq/Ft. | Actual Watt/Sq. Ft. | COMCheck Compliance Rate |
| Dining/Conference | 1.0 | 0.7 | 38 |
| Gymnasium/Support | 1.3 | 0.5 | 60 |
| Industrial/Office | 1.4 | 2.0 | -38 |
| Industrial/Storage | 1.5 | 1.0 | 31 |
| Industrial/Storage | 1.5 | 1.1 | 23 |
| MultiFamily/Support | 1.0 | 0.2 | 82 |
| MultiFamily/Support | 1.0 | 0.2 | 82 |
| Retail/Office | 1.5 | 1.1 | 27 |
| Retail/Storage | 1.4 | 2.1 | -51 |
| Restaurant/Support | 0.9 | 2.1 | -124 |
| Storage/Medical | 1.1 | 0.7 | 32 |
| Storage/Office | 0.9 | 1.0 | -16 |

**Table 2.5.1.1(2)**

Section 2.5.1.2 Mandatory Requirements*.* The mandatory requirements for lighting were reviewed during the plan review process. Information was collected when it was available from the lighting plans. The field collection team was requested to verify that the features were installed in the building. The following items were reviewed:

- Independent lighting control (each space separately switched)
- Bi-level switching where applicable (ability to reduce the overall lighting level in a space by at least 50%)
- Photocell or time clock control on exterior lighting
- Exterior lighting source type (IECC requires exterior lighting to be 45 lumens/watt or greater)

Because each of the features was not always designated on the lighting plans, the plan reviewer was asked to record the frequency of projects that were in compliance with each of the mandatory requirements. Twenty-six projects complied with the independent lighting control requirement. Only 3 of the projects installed switching that would meet the bi-level switching requirement. Based on experience in states that have adopted the IECC, bi-level switching is normally not designed into projects unless required by code.

The designation of an exterior lighting control, either a photocell or a time clock with seasonal adjustments was found on 13 of the projects. Often, photocells are installed in conjunction with a time clock that will turn the exterior lights off for a portion of the evening. Information on exterior lighting was found on 26 of the projects. The lighting found on 24 of the projects installed lighting that met or exceeded the 45 lumens/watt minimum requirement. The lighting sources that met the requirements included:

- Metal Halide
- High Pressure Sodium
- Fluorescent
- Compact Fluorescent

Two projects proposed incandescent lighting as the light source for exterior lighting and did not meet the 45 lumens/watt minimum efficacy requirement.

**Section 2.5.2 Inspection.** The field collection team used the data collection forms for the lighting system to verify that the information presented on the lighting plans was correct or to collect additional information missing from the plans. The field inspection staff collected necessary information to complete the lighting study on several of the projects.

Several of the mandatory features discussed in Section 2.5.1.2 were verified in the field. In certain cases, the features were not readily apparent on the plans but were found in the field. Also, lighting sources were verified in the field if there was insufficient information on the lighting plans. For example, the number and type of bulbs in fluorescent fixtures were confirmed in the field in addition to the wattage of incandescent lighting installed in can lights. In smaller projects the field team corrected the fixture count shown on the data collection form. They were requested to spot check the number of fixtures to verify that the count on the data collection form was within reason. Actual fixture wattage was corrected, and increased in at least one project.

## SECTION 3.0 DATA COLLECTION PROCESS

The discussion that follows describes the process and assumptions used to complete the project. In general, the assumptions that we were used were conservative as would be required by the IECC if sufficient information were not available on the plans or documentation.

### *Section 3.1 Data Collection Form Development*

A data collection form was developed for use with the plan review portion of the study and that could be taken into the field to confirm energy efficiency values noted on the plans. The input screens from the COM*check-EZ* software were used as a basis for the form. This allowed easy input from the form to the software during the data analysis portion of the study.

The survey instrument was developed using Microsoft Excel. Using Excel for the development of the instrument allowed the data collection staff to complete the form on laptop computers and than email them to the computer where the data analysis occurred. Completing the forms on computer allowed the files to be sent back and forth between the plan review data collection staff and the field collection staff.

### *Section 3.2 Plan Review Process*

The plan review was conducted in two stages. Ron Oltman, Energy Solutions was contracted to perform the initial plan review and to complete the data collection form developed under Section 3.1 for the building envelope, lighting and mechanical systems. Any assumptions due to inadequate or missing information on the building plans were recorded on the data collection forms. BMG then reviewed each of the data collection forms to ensure completeness and to review the assumptions. If a data point was in question or missing, it was highlighted on the data collection form to ensure that the field collection team could confirm or collect the information. It was important that the assumptions were consistently applied to all projects. The description that follows provides more detail on plan review for each of the disciplines.

**Section 3.2.1 Building Envelope.** Building envelope data was collected for all parts of the building that surrounded conditioned space as defined by the IECC. This included data for the roof/ceiling assembly, wall assembly and floor assembly. For buildings that included an unconditioned space attached to a conditioned space, e.g. an office/warehouse building, the wall between the two spaces was documented as an "Interior Wall" per the guidelines in the IECC. A portion of the projects selected were in existing shopping centers where the scope only included the addition of a mechanical and lighting system. The building shell was not considered in these cases.

Section 3.2.1.1 Assumptions. Several assumptions were made in order to perform the COM*check-EZ* analysis. Where possible, the field collection staff verified the assumptions in the field or modified them to reflect actual conditions. The following assumptions were made:

*Section 3.2.1.1.1 Glazing U-factor*: The field staff had a difficult time verifying glazing U-factor at the site due to lack of information. A portion of the windows were site-built, curtain wall or store front which typically are not labeled with NFRC labels. If window efficiency information was included on the plans, the field team attempted to verify that this was installed in the field. Where efficiency information was absent on the plans, the field team depended on collecting information that included the frame type and number of panes of glass.

This information was then used to select a default glazing U-factor in COM*check-EZ*. The 1989 ASHRAE Handbook of Fundamentals is used as the reference for default U-factors within the software. This approach is consistent with how a designer would document glazing U-factor if no information is available and is typically conservative on the rating provided to the window. Actual manufacturer rated values are normally lower (more efficient) than the default values.

*Section 3.2.1.1.2 Glazing Solar Heat Gain Coefficient (SHGC):* As with the Glazing U-factor, the SHGC values were difficult to verify in the field due to lack of information and NFRC labeling. The actual values were used if identified on the plans or verified in the field. If no information was available, windows were assumed to be clear which is viewed as being conservative. COMcheck-EZ uses SHGC values from the 1989 ASHRAE Handbook of Fundamentals when the documentation author selects a default value. This values are conservative and actual rated SHGC values are normally lower (more efficient) than the default values.

*Section 3.2.1.1.3 Roof/Ceiling Insulation*: Assumptions were used for roof/ceiling R-values in metal building where only structural plans were submitted. Typically insulation will be draped between purlins with a protective cover placed under the insulation to act as support, meet the fire requirements for the building and to reduce condensation on the roof assembly. Condensation on the underside of the roof assembly can occur if space conditioning equipment is installed e.g. a unit heater. In these cased an R-19 insulation was assumed with no thermal blocks between the purlin and roof deck.

*Section 3.2.1.1.4 Wall Insulation*: A portion of the plans included no information on wall insulation R-value. These plans typically where for metal buildings. An R-11 insulation installed between metal framing was assumed for these installations.

*Section 3.2.1.1.5 Slab Edge Insulation*: The field staff were not able to verify the presence of slab edge insulation for most projects. Information was collected from the plan details for this input unless the inspection team was on site prior to backfill. The IECC requires that slab insulation be installed from the top of the slab down or down and horizontal. Insulation that does not cover the slab edge is disallowed under the code. Based on the plan details, a slab with insulation stopping under the slab was counted as an uninsulated slab.

*Section 3.2.1.1.6 Doors*: There was typically very little information about door efficiency on the building plans. Doors were classified as either opaque (≤50% glass) or glass (>50% glass) or an overhead door. The COM*check-EZ* default values were used to assign a U-factor and SHGC if applicable. These values are from the 1989 ASHRAE Handbook of Fundamentals.

**Section 3.2.2 Mechanical Systems.** Mechanical system information was collected using the input fields from the COM*check*-*EZ* software as a guide. The input fields use the mechanical system type, size (capacity) and fan system type to assign the applicable IECC requirements. For multi-zone systems information on the variable air volume fan systems are required to be collected. There are no trade-offs for increased system efficiencies under the IECC only a set of prescriptive requirements that systems must meet.

Section 3.2.2.1 Assumptions. Few assumptions were made when documenting the mechanical system as many of the plans contained information necessary to document the buildings. Where possible, the field collection staff verified the assumptions in the field or modified them to reflect actual conditions. The following assumptions were made:

*Section 3.2.2.1.1 System Size*: If the size of the cooling system(s) was not specified on the plans, the following process was used to approximate the capacity. A "rule of thumb" of 400 $ft^2$ of conditioned floor area per ton of cooling was used to determine an approximate capacity for the building. The total tonnage was then divided by the total number of cooling systems shown on the plans to approximate system capacities. Heating system capacities were not considered unless the building used a boiler so it was not necessary to apply a rule of thumb to determine heating size.

For single zone cooling systems, system sizes were collected based on range of capacities. For example all systems less than 65,000 Btu/h were classified as <65,000 Btu/h without further breaking down the system capacities into smaller increments (e.g. 36,000 Btu/h, 48,000 Btu/h, etc). The IECC requires cooling systems greater than 65,000 Btu/h to have an economizer and does not require a further breakdown for systems less than this threshold.

*Section 3.2.2.1.2 Economizers*: Economizers were only documented for systems when called out on the plans. Economizer installations were verified in the field when possible.

*Section 3.2.2.1.3 Temperature Controls*: Temperature controls were only documented if called out on the plans. Temperature control installations were verified in the field when possible. No reporting was done on temperature controls under the findings portion of this report.

*Section 3.2.2.1.4 Duct Sealing/Insulation*: The mechanical plans typical lacked information on duct insulation R-values and sealing methods. This information was recorded in the field where possible. No assumptions were made if information was not on the plans or collected in the field.

**Section 3.2.3 Lighting Systems.** Lighting system information was collected using the input fields from the COM*check-EZ* software as a guide. This included fixture type, ballast type for ballasted fixtures, number of bulbs, fixture wattage and total number of fixtures installed. The electrical plans and lighting plans were used to collect this information and the information was verified in the field if possible. A portion of the projects did not include lighting plans or the plans only called out fixture placement without other information as to type or wattage. Lighting was not documented for these projects due to the variability of the lighting type and wattage.

The occupancy type for each of the projects was assigned based on the predominant occupancy for each building. For example, a retail space was classified as a single occupancy retail even though an office area was included on the plans. This was done to determine the installed watts per square foot and compliance margin for a variety of occupancy types.

Section 3.2.3.1 Assumptions. Several assumptions were made in order to perform the COM*check-EZ* analysis. Where possible, the field collection staff verified the assumptions in the field or modified them to reflect actual conditions. The following assumptions were made:

*Section 3.2.3.1.1 Lighting Power Allowances*: For the retail lighting power allowances, either the whole building or tenant/partial building categories were assumed. No additional credit was given for display lighting as allowed by the IECC. An additional 1.6 watts/ft$^2$ for general merchandise display or 3.9 watts/ft$^2$ for merchandise requiring higher lighting levels is allowed if the lighting is identified on the lighting plans.

*Section 3.2.3.1.2 Lamp Ballast Type*: Electronic ballasts were assumed for all HID and fluorescent fixtures. This is typical for these types of fixtures.

*Section 3.2.3.1.3 Watts Per Fixture*: Watts per fixture is typically not included on the electrical plans for ballasted fixtures. The IECC requires that the wattage of the bulb and ballast be documented for compliance with the code. If the wattage if the fixture was included on the lighting plans it was included in lighting compliance documentation. A lighting default wattage was selected from the COM*check-EZ* software when no wattage was provided for the fixture. Typically this wattage is conservative (has a greater wattage than the actual light fixture) which will result in a higher watts/ft$^2$. Incandescent fixtures were assigned the wattage of the bulb specified for the fixture.

**Section 3.2.4 Success and Issues for Plan Review Data Collection.** The plan review data collection process was found to be successful and identified several issues that will need to be addressed if a commercial energy code is adopted by the state of Indiana. The following successes and issues were identified for each of the energy using features.

Section 3.2.4.1 Building Envelope. The IECC requires that the energy using features used to demonstrate compliance be identified on the building plans. Because the state of Indiana currently has not adopted a commercial energy code, the building plans were not required to contain this information. Regardless of the state requirements, many of the efficiency levels in the building envelope were called out on the plans. This includes the R-value of the ceiling, wall and floor insulation. Typically missing was any information on glazing efficiencies and SHGC. This required either the field data collection team to verify this in the field or to use a default value for the windows. Areas for each of the assemblies were easy to access from the plans. Either a window schedule or the rough opening of the windows were typically provided on the plans. Window dimensions could also be scaled off the plans when not provided.

The plans were typical of what would be expected in a state with no energy code requirement or a state where the energy code has just been adopted. Commercial building plans typically contain more information for the envelope than residential projects and have fewer changes in the field. This increases the value and reliability of plan review data over similar residential projects, even without corresponding field data.

### *Section 3.3 Field Inspection Process*

The Baseline Study used inspectors employed by the Indiana Department of Fire and Building Services (IDFBS) to collect and verify data in the field. IDFBS inspectors selected for performing data collection for two primary reasons:

1. Inspection staff had immediate access to each of the selected sites because they were required to inspect for other building, mechanical and electrical code items as part of their responsibilities. Gaining access to construction projects has been an issue in past residential data collection projects so using the inspectors who would ordinarily inspect eliminated this problem.

2. The data collection project provided training for the inspectors and on-the-job experience in looking for energy related features. The inspector’s role is critical in implementing an energy code so providing advanced training and on-the-job experience prior to a code being adopted will go far to gaining compliance with the code.

The following process was used in the field data collection portion of the baseline study.

**Section 3.3.1 Training of Inspectors.** A two-day training session was held for the IDFBS state inspectors. The goal of the training session was to instruct the inspectors on how to collect commercial energy code data in the field. Day one of the training was held in the classroom and provided an overview of the commercial provisions of the International Energy Conservation Code as it related to field inspectors. The data collection form was also covered to ensure that the inspectors understood where to look for the information on the forms. Day two of the training session was conducted at three commercial building sites. A data collection sheet was developed for one of the sites, a 67,000 $ft^2$ building, and provided for the class attendees. This sheet was used as the basis for the training. The two other sites were used to reinforce areas of the commercial code that could not be done at the main training site. One of these sites was a multi-family building which is considered as a commercial occupancy by the state of Indiana.

**Section 3.3.2 Field Inspections.** Once the data collection forms were reviewed by BMG, they were sent to the IDFBS for distribution to the field inspectors. BMG provided guidance on what to review in the field for each of the projects. Each of the data collection forms included the following instructions:

> Field Inspection Notes
>
> Please Note: Inside This Packet are Highlighted Areas to Check. They Include:
>
> - Questions we had on the plans
> - Verify insulation levels
> - Verifying of identifying types of windows
> - Verifying mechanical system types and sizes
> - Verifying economizer installed on each system
> - Verify all envelope requirements
> - Spot check lighting types
> - Switching requirements
> - Comments
> - Noticeable omissions

It is important to note that BMG did not require that the IDFBS inspectors review every energy feature in the building. The first priority was for the inspectors to review data that could not be collected from the plans. This included missing insulation levels, glazing type, light fixture type, etc. The second priority was to have the inspectors review items which are typically not on the plans but must be reviewed in the field. This includes air sealing for the building envelope, duct insulation and duct sealing as an example. The third priority was to have the inspectors review items that would ordinarily be reviewed by the inspector during a typical field inspection. For example, this would include spot checking the lighting source type and number of fixtures. Given manpower constraints it was not expected that the inspectors review every energy item in the field for this baseline project.

Because the inspectors are located throughout the state, the IDFBS main office distributed each of the projects to the applicable inspector to review. As with all baseline projects, there were both successes and issues that impacted the field portion of the study.

**Section 3.3.3 Successes and Issues for Field Inspection**. All of the field inspection staff were experienced in inspecting for code requirements other than the provisions of the IECC. The training provided under Section 3.3.1 provided a background of information for the inspectors to use in collecting data. They also were left with the ability to contact BMG staff to clarify items. But the inspectors faced the same issues that jurisdictions face once a municipality has adopted the new energy code. This was slightly compounded because the state had not adopted the IECC.

A portion of the buildings were already constructed prior to receiving the data collection forms. The inspectors did their best to collect missing data and verify the information. Inspecting for Insulation thickness for built-up roof systems was problematic as has been the case in several states that have adopted the IECC. Gravel or another covering is applied over the insulation making it difficult to determine thickness. In a few cases the inspectors made several trips out to the site to collect the required data. A few of the buildings were not started during the data collection process and so only have plan review data was available.

Other issues that occurred in the field concerned collecting glazing U-factor and SHGC values from store front, curtain wall or site built windows. This proved to be difficult and is consistent with the problems verifying this data in states that have adopted IECC. Verifying lighting wattage was a challenge especially in areas with high bay lighting where the fixtures could not be reached.

Because of the problems and issues in the field, 35 of the original 50 buildings were field inspected and an additional 5 buildings were added to the study for plan review only.

### *Section 3.4 Data Base Development*

Initially it was thought that Microsoft Access would be the software used to collate and analyze the data collected. However, upon review of the plan review and field inspection data, it was determined that Microsoft Excel would better provide for the analyzing the type of data collected in the study. The data received from field inspections varied greatly, and was not large batches of consistent data more suited to analysis in Access. The primary data collected was entered into a set of worksheets for analysis, and the findings were made with smaller spreadsheet calculations and visual reviews rather than large batch calculations and data queries as anticipated at the onset of the study.

### *Section 3.5 Analysis Tool*

The U.S. Department of Energy's COM*check-EZ* 3.0 Release 1 was selected as the analysis tool to determine compliance for the building envelope, mechanical and lighting systems. COM*check-EZ* is the commonly used energy code compliance tool for demonstrating compliance with various versions of the IECC in states that have adopted the code. The software provides a rate of compliance for the building envelope and lighting system and a list of requirements for the mechanical system based on configuration. It should be noted that COM*check-EZ* only considers compliance with the energy code and does not analyze the actual energy used by the building features.

## SECTION 4.0 RECOMMENDATIONS

The recommendations that follow are based on the findings presented in this report:

**Recommendation One**: The State of Indiana should pursue adoption of the 2003 IECC for commercial buildings or the more efficient 2006 edition of the IECC that will be published in 2006. Based on current practice, the building envelope for several classifications of buildings will comply with the thermal efficiency requirements of the IECC. More complete and accurate documentation for the buildings that did not comply with the code may show that the compliance deficits are less or that the buildings comply. In general most buildings comply with the mechanical provisions of the IECC. Although equipment sizing is still in question, based on the items that were checked, duct insulation may be an issue. Compliance with the lighting requirements in the IECC will present the greatest challenge for the state. Current practice shows that lighting levels are higher than allowed by code for most classifications of single occupancy buildings. Better lighting design practices and higher efficacy light sources can be used to bring lighting into compliance with the IECC. Also, using the additional lighting power allotments for display, decorative, visual display and medical lighting may bring current practice into compliance.

**Recommendation Two**: More complete information should be required on the plans or documentation to determine compliance with the IECC. This study found insufficient information to determine compliance for the building envelope, lighting and mechanical system. The information contained in the COM*check-EZ* documentation can be used as a substitute for plan notes but several of the mandatory features cannot be covered by plan notes and must be depicted on the plans. For example independent lighting control and bi-level switching must be shown on the plans.

**Recommendation Three**: Training will be critical for the building design and enforcement industry to increase the implementation rates of the IECC. The following training programs are recommended:

Enforcement Training – Plan Review: Plan review staff must be trained to ensure that the plans and documentation are complete, have been performed correctly, and meet the requirements of the IECC. If the plans and documentation are complete it provides a valuable tool for the inspector in the field.

Enforcement Training – Inspector: The IDFBS inspectors performed well in the field given the limited number of contact hours in training. Effective commercial energy code training for inspectors must be conducted in both the classroom and in the field.

Building Design and Engineer Training: Training must be deployed for the building design and engineering community. The training must clearly outline the requirements of the code provisions and what documentation will be required for submittal to the IDFBS. The training must also contain components on lighting strategies that can be using to comply with the lighting requirements of the IECC.

Recommendation Four: Technical assistance to the design, engineering and enforcement community must be established. The technical assistance must readily accessible to all and must offer consistent answers to questions and consistent interpretations. This has been critical for code implementation in the state of Idaho, California and Washington and has been set up in Nevada as they move toward adoption of the IECC.